Coherent electron Cooling Systems Run 17 beam experiments

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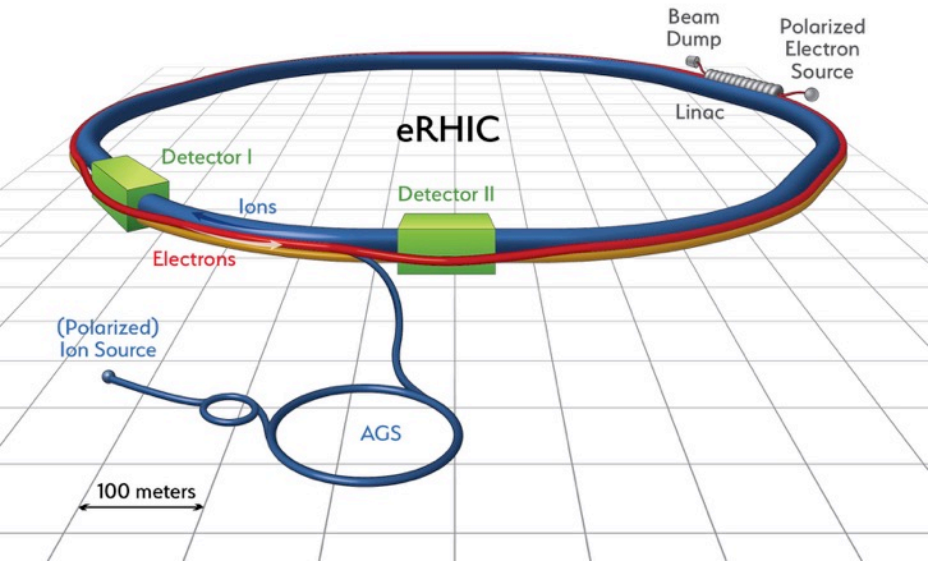
APEX Workshop 2016

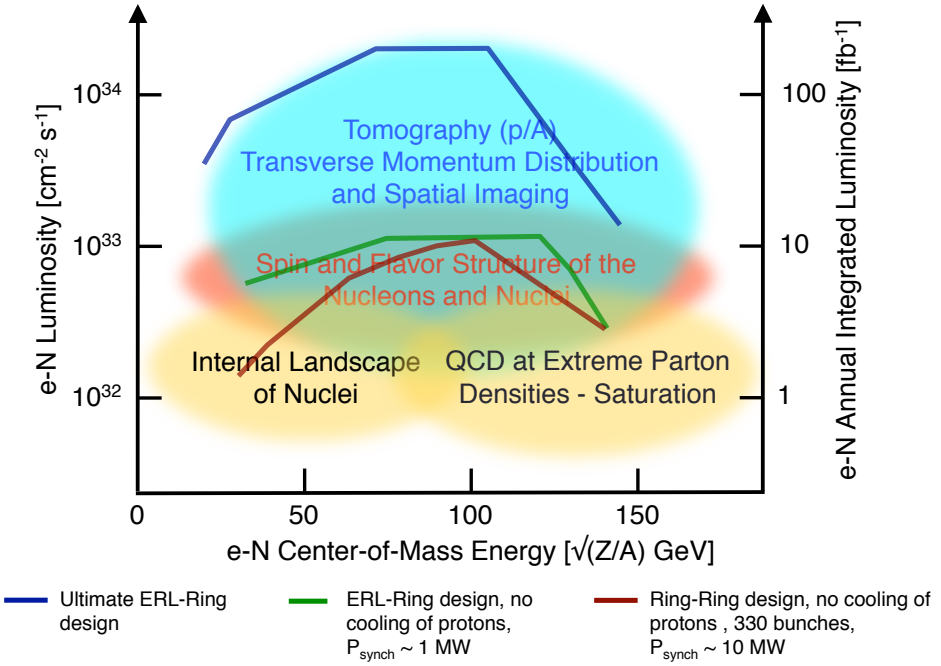
Outline

- Why we doing this?
- What is CeC PoP?
- Where are we?
- Where are we going?
- APEX role and APEX experiments
- Conclusions

HIGH ENERGY HIGH LUMINOSITY EIC REQUIRES STRONG HADRON COOLING:

ULTIMATE REQUIREMENT < 1 MIN COOLING TIME @ 250 GEV PROTONS





Coherent electron Cooling (CeC) is needed to achieve the ultimate high luminosity in any EIC and has to be tested -> CeC PoP

CeC effect on eRHIC design

Short term: If CeC is successful and is fully operational, eRHIC LR would reach 2×10^{33} luminosity with 5 mA polarized electron current.

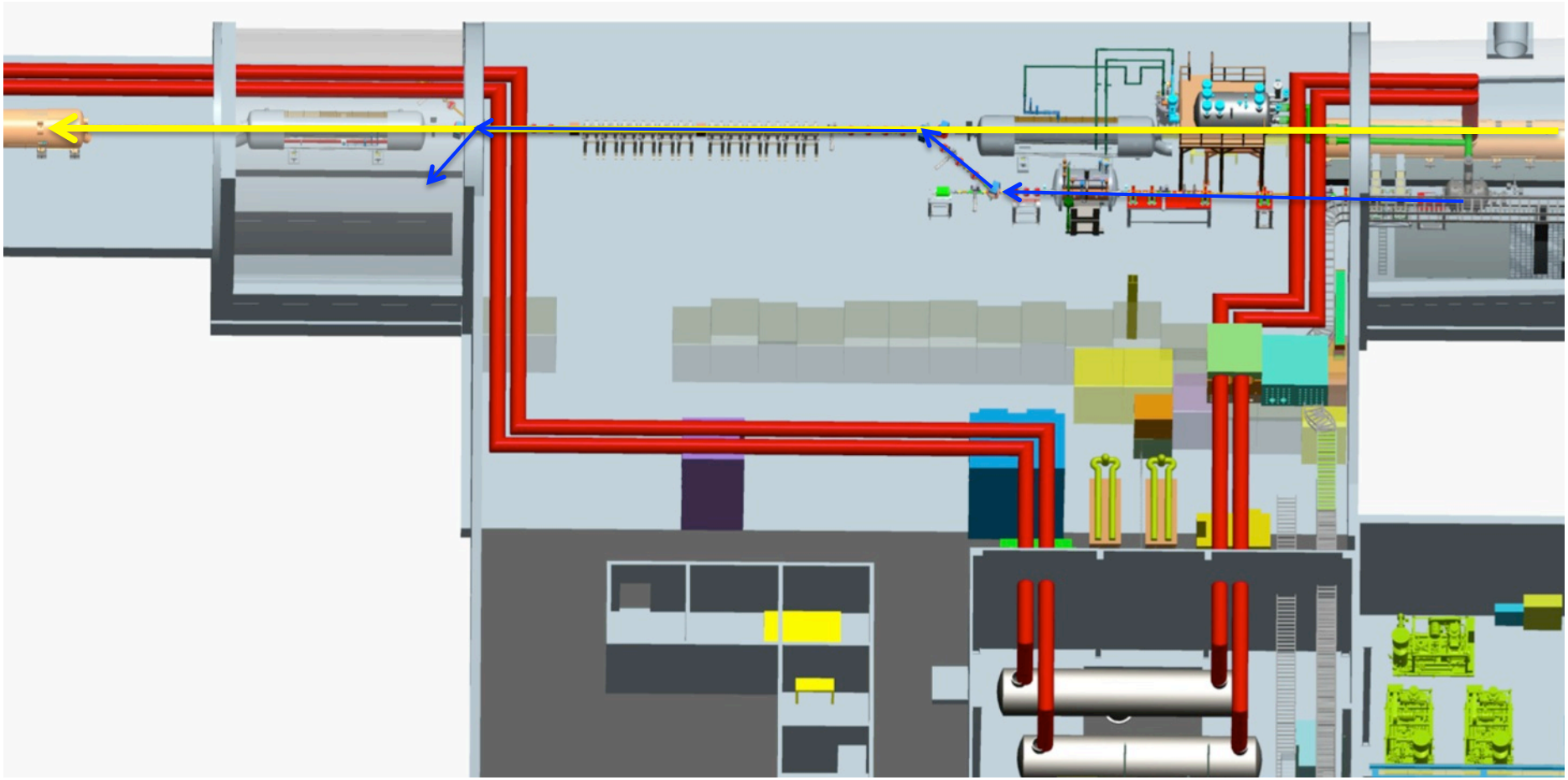
It removes main uncertainties in initial LR eRHIC design

– 50 mA of polarized e-beam to 5 mA, 0.5 nC/bunch

- 100x lower HOM power
- 10x lower TBBU threshold
- 10x lower SR losses
- 10x lower SR back-ground
- and many positive effects for EIC detector

Final goal: eRHIC with 2×10^{34} luminosity

CeC Proof-of-Principle Experiment



Coherent electron *Cooling* PoP

Main Beam Parameters for CeC Experiment

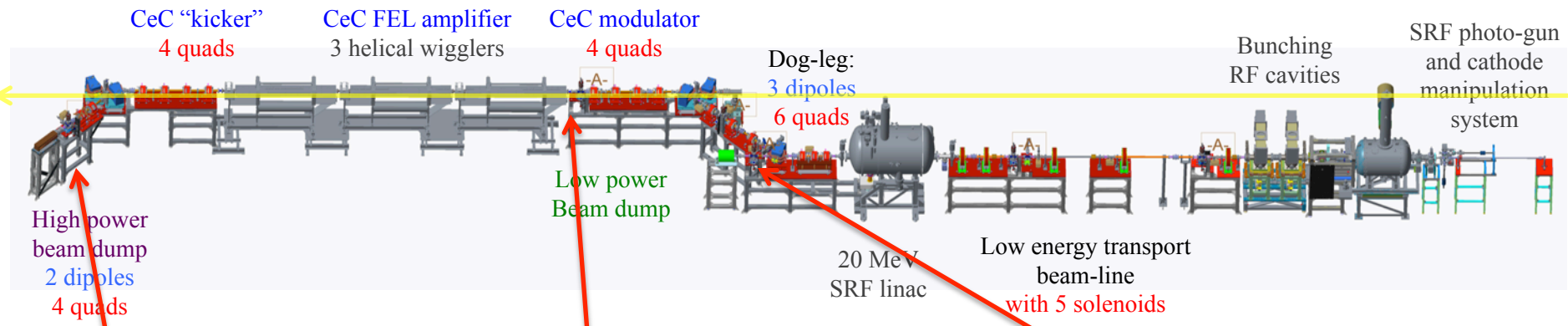
Parameter	Value	Status
Species in RHIC	Au^{+79} ions, 40 GeV/u	✔
Relativistic factor	42.96	✔
Particles/bucket	10^8 - 10^9	✔
Electron energy	21.95 MeV	< 10 MeV
Charge per e-bunch	0.5-5 nC	✔ (> 3.5 nC)
Rep-rate	78.17 kHz	5 kHz*
e-beam current	0.39 mA	Few μA
Electron beam power	8.6 kW	< 10 W

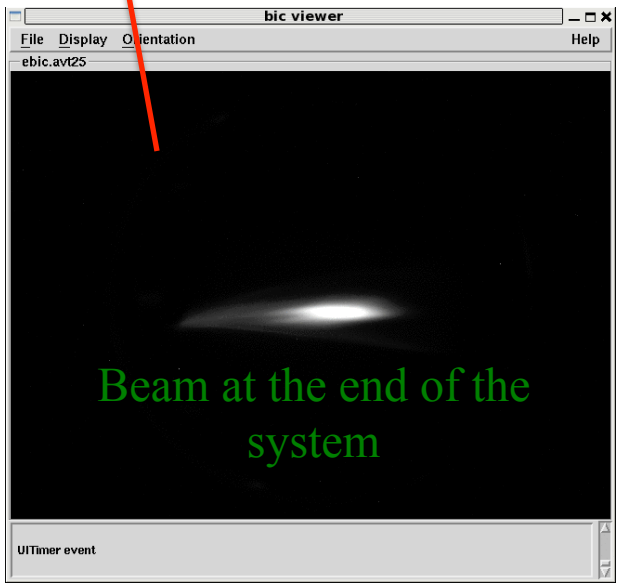
** We did not operated 5 kHz with 3.8 nC per bunch at the same time*

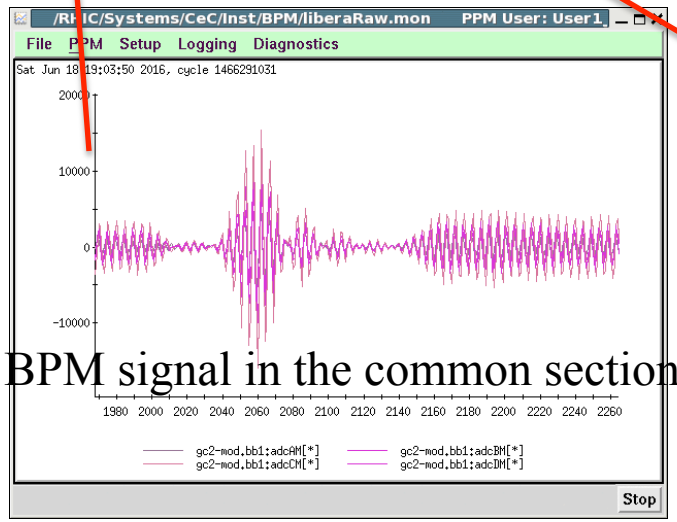
*** Numbers listed in blue do not require modification of equipment*

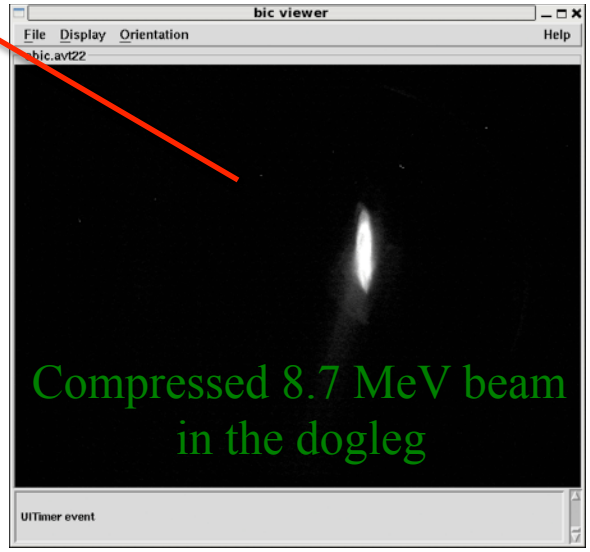
The CeC system commissioning

Common section with RHIC









Beam was generated, compressed, accelerated to about 8 MeV and propagated through the entire system to the high power beam dump

Big picture

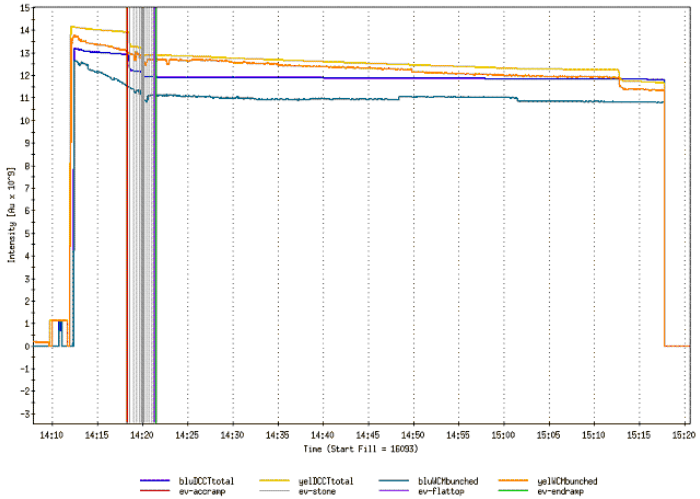
- Shutdown – repairs and improvements
- Run 17
  - Finish commissioning of CeC accelerator at full energy and power: 21 MeV, 78 kHz, few nC
  - Establish interactions with ion beam
  - Establish FEL amplification
  - In the best case: Cool ion beam
- Run 18
  - Reestablish CeC operation
  - Characterize CeC cooling

Run 17

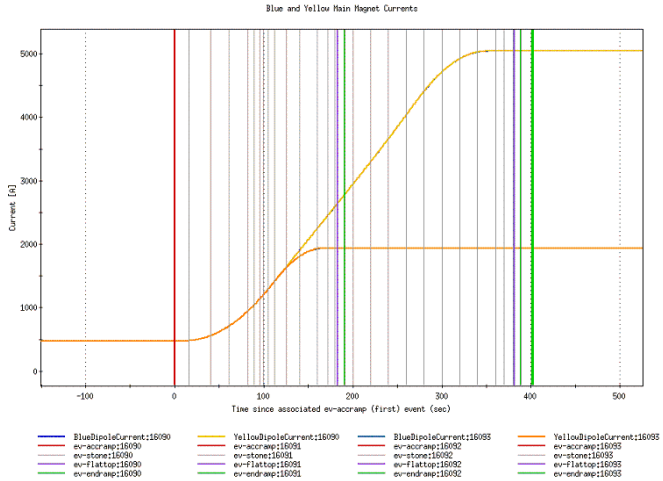
- Most of CeC activities -in parallel with RHIC operation:
  - Re-commissioning of the accelerator
  - Low power beam propagation to the HP beam dump
  - Establishing FEL amplification, Run 17
  - ….
- We plan to use APEX for establishing new modes of operation
- – 2 weeks of dedicated time is needed - spread over the run
  - Establishing interaction between the ion and e-beam
  - FEL Amplification of the interaction
- The best scenario:
  - Attempting CeC cooling of ion beam
- *Regular scenario:*
  - *CeC cooling of ion beam and its evaluation during Run 18*
- *Resources needed*
  - *Technical support for cathode making/transport/exchange*
  - *Technical support for maintaining all CeC systems: cryo, SRF/RF, magnets, vacuum, diagnostics, controls, MPS, PPS*
  - *Help for RHIC operators with RF conditioning and maintaining "routine" operation mode of CeC systems*

Re-establishing RHIC Ramp for CeC PoP
Evaluate ion beam evolution, test diadnostics

Ramp : beam intensity

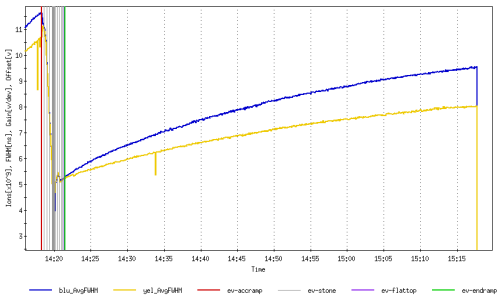


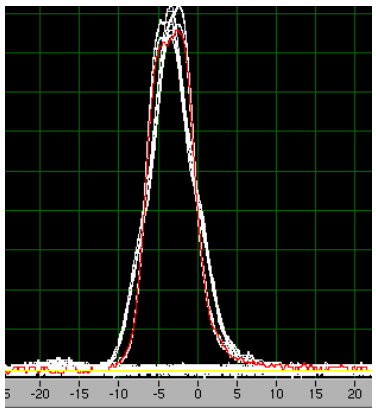
Ramp : Magnets currents



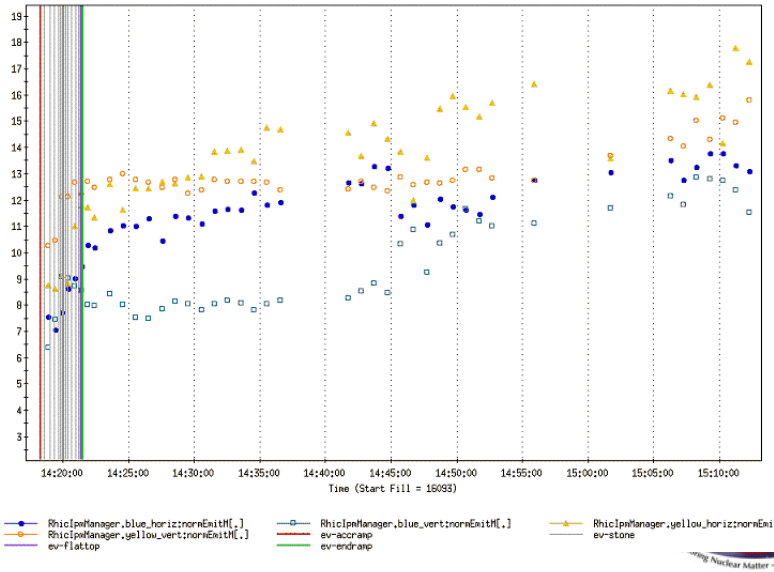
APEX on RUN 11: 2pm-4pm, June 20th , 2011 Fill: 16093

Bunch length and profiles at 40 GeV





Emittance growth at 40 GeV

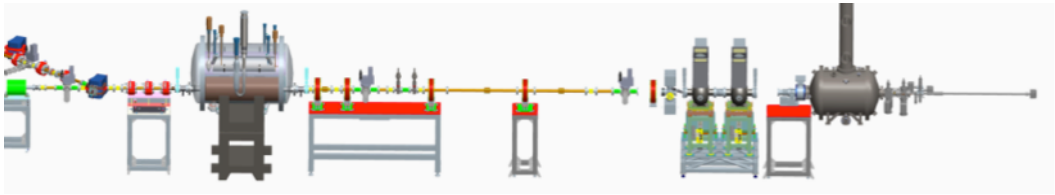


Steps in CeC PoP comissiong

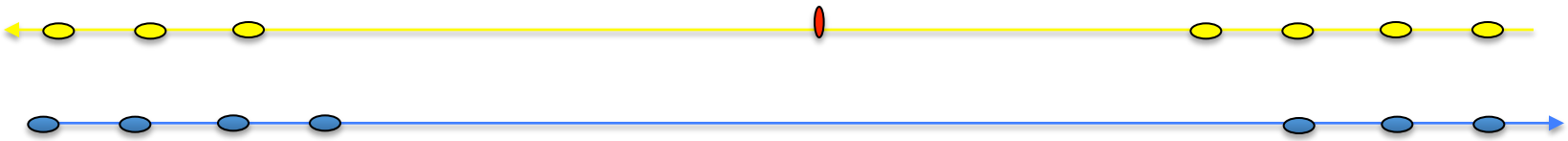
1. Conditioning – re-commissioning of CeC RF system (112 MHz, 500 MHz & 704 MHz) to design voltage, synchronized with 78 kHz tone, full control of voltage and phase
2. Accelerate beam to 20 MeV and beam power under 1W
3. Measure beam parameters (charge, emittance, peak current, energy spread…)
4. Increase beam power 10x: 1W -> 10 W ->100 W – 1kW -> full power
   - follow increases by radiation surveys (and fault studies <10 W)
5. Propagate full power 20 MeV e-beam to the beam dump, match the beam into FEL
6. Commission IR FEL diagnostics and demonstrate FEL amplification
7. Co-propagate, align and synchronize electron and ion beams
8. Match relativistic factors (velocities) of hadron and electron beams
9. Observe amplification of the density modulation
10. Attempt to observe local cooling

How we will operate in parallel with RHIC

- Commissioning of CeC accelerator
  - Parallel to RHIC operation, except occasional requests for access



- Propagating electron beam through the IP2 to the dump
- Parallel to RHIC operation: electron bunches passing through the IP2 during Blue abort gap and between 2 yellow bunches



Propagate Electron Beam to High Power Dump

No beam in both rings

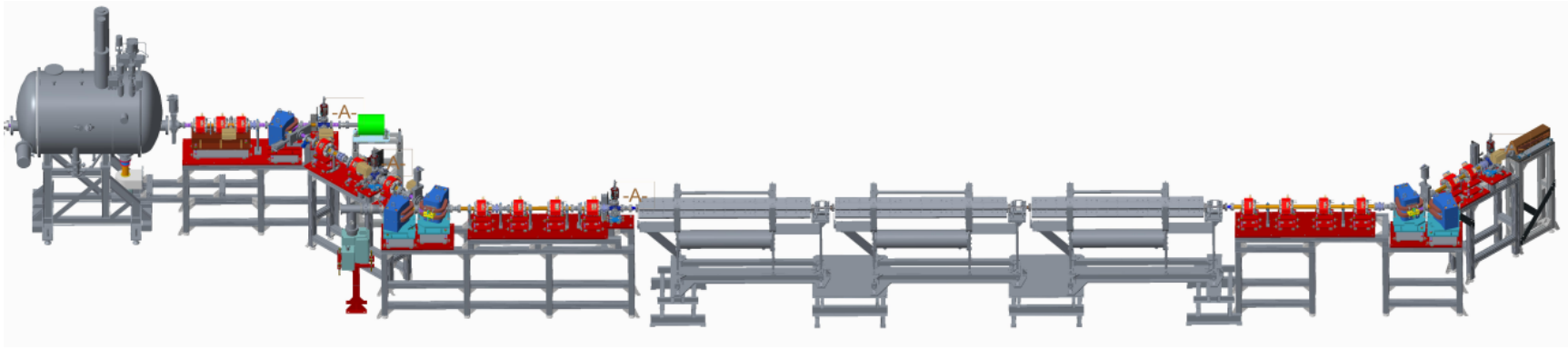
Deliver low power beam to all way to the high power dump

Beam profile will be observed on the profile monitor in the common section

Start tests of the high frequency BPMs, ICT near the high power dump, Faraday cup signal, profile monitor in front of high power beam dump

Measure beam optics (wigglers are opened)

Two sessions – four hours each



Fault Studies

No beam in both rings

Electron beam will lost in the controlled manner (with MPS re-configured to allow higher losses)

- **at pepper-pot**
- **at low power dump**
- **on the dogleg valve**
- **on the profile monitor in the common section**
- **on the valve separating high power beam dump**

One session, four hours

Reaching Full Power Electron Beam

No beam in both rings

Increase gradually duty factor of laser power and hence average beam current

Perform radiation surveys outside shielding and dump

Establish nominal currents for the last two quadrupoles and window for operation

Commission BPMs, MPS

Measure offsets between high and low frequency BPMs

Measure phase shift between pick-up electrodes (coarse energy match)

Three sessions – six hours each

Commissioning of IR Diagnostics

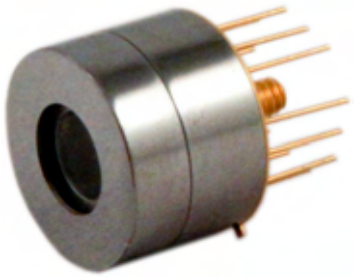
No beam in both rings

Measure FEL radiation spectrum and transverse profile

Measure FEL gain

Adjust phase shifters

Two session – four hours



Matching Hadron and Electron Beams

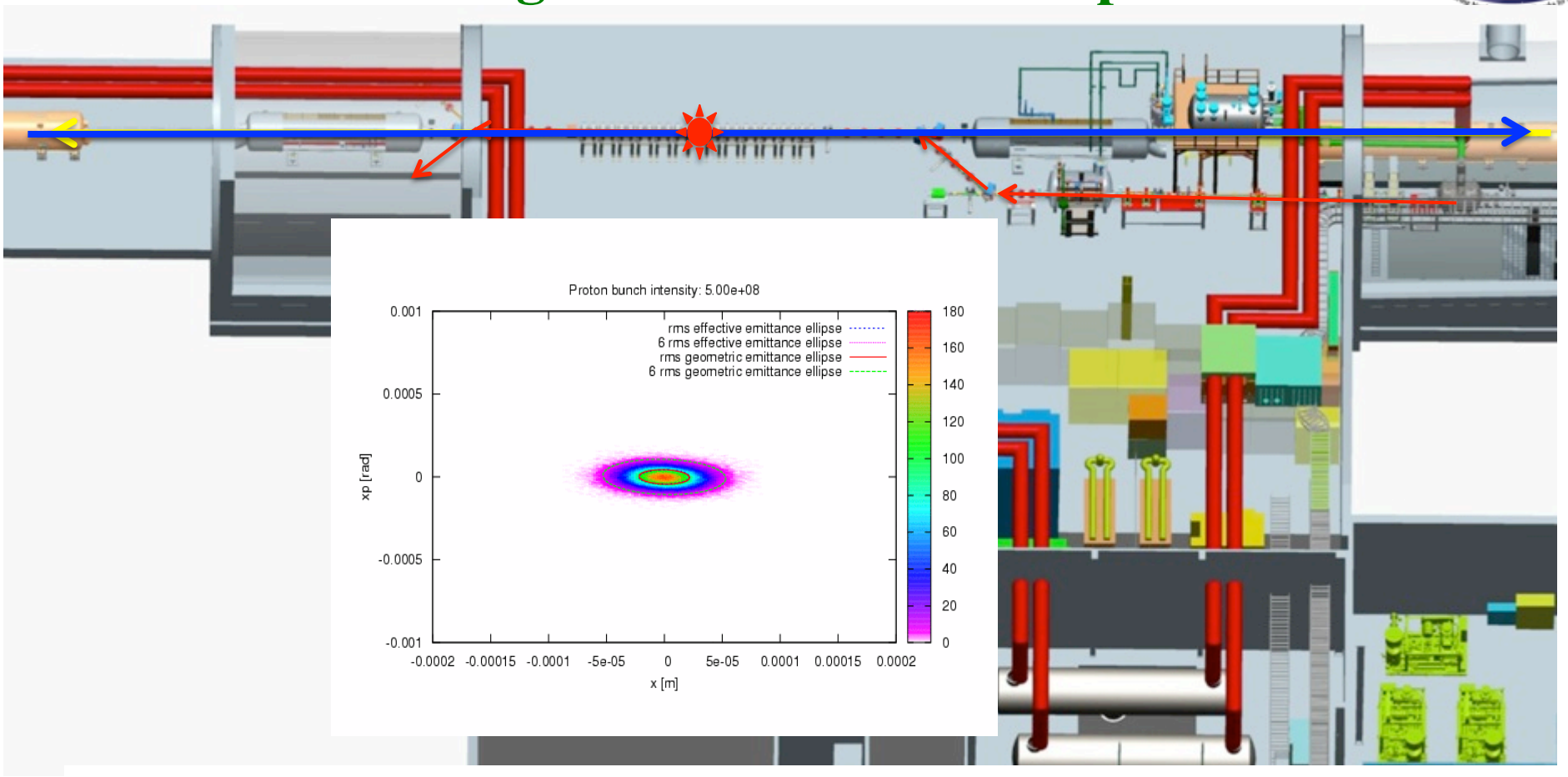
- Run at CeC PoP energy
- Gold ions in the yellow ring at CeC PoP energy
- No beam in the blue ring
- Observe signals from the pick-up electrodes on an oscilloscope and adjust cogging that electron bunch (low power beam) will be on the top of the hadron bunch
- Observe growth of FEL power with matching of the hadrons' and electrons' relativistic factors (high power beam)
- Two sessions – six hours each

CeC PoP system at RHIC allows to test following EIC risks/R&D issues

- Conventional bunched electron cooling at 40 GeV/u
- Effects of electron bunch-charge modulation on cooling/heating of hadron beams
- Linac-ring beam-beam effects:
  - Pinch effect of electron beam
  - Kink instability
- Critical aspect of micro-bunching amplification
- Compensation of the tune spread in hadrob beams induced by the space charge

We plan to include first three items as part of APEX for RHIC Run17

Three straight-forward APEX experiments



Bunched e-cooling – open helical wigglers, adjust optics

Linac-Ring beam-beam

- collision experiment with hadron in blue ring
- observe hadron emittance growth caused by fluctuation of bunch charge

Coherent electron *Cooling* PoP

Conclusions

- ✓ **We will continue CeC commissioning during Run 17**
- ✓ **A number of critical steps would be done as part of APEX**
  - ✓ Establishing “In-gap” mode of CeC operation
  - ✓ Fault Studies
  - ✓ Reaching Full Power Electron Beam
  - ✓ Commissioning of IR Diagnostics
  - ✓ Matching Hadron and Electron Beams
- ✓ **There are 3 experiments relevant to RHIC and eRHIC and which will be done using CeC PoP accelerator**
  - ✓ Testing bunched e-cooling at high energy
  - ✓ Studying linac-ring beam-beam effects
  - ✓ Emittance growth caused by noise in e-beam